



MARINE BIOLOGY RESEARCH DIVISION
SCRIPPS INSTITUTION OF OCEANOGRAPHY

9500 GILMAN DRIVE
LA JOLLA, CA 92093
PHONE: (619) 534-42447
FAX: (619) 534-0300

November 26, 1997

Dr. Ronald Tipper (3)
Scientific Officer
Office of Naval Research
Ballston Tower One
800 North Quincy Street
Arlington, VA 22217-5660

Administrative Grants Officer (1)
Office of Naval Research
San Diego Regional Office
4520 Executive Drive Suite 300
San Diego CA 92121-3019

Director, Naval Research Laboratory (1)
Attn: Code 2627
Washington, DC 20375

Defense Technical Information Center (2)
8725 John J. Kingman Road, Ste. 0944
Ft. Belvoir, VA 22060-6218

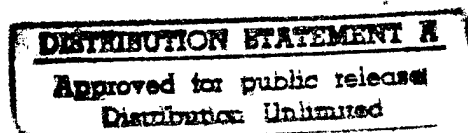
Office of Naval Research
Ballston Tower One
Attn: ONR OCCC1, Mr. William F. McCarthy
800 North Quincy Street
Arlington, VA 22217-5660

SUBJECT: Final Technical Report
ONR Award No. N00014-95-1-0142
PI: Lanna Cheng

Enclosed for your records is the final technical report for the referenced grant along with the required number of copies as outlined in the award document.

Sincerely,

A handwritten signature in dark ink, appearing to read "Judy Keplinger".
Judy Keplinger
Contracts & Grants Assistant



DTIC QUALITY INSPECTED 4

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average one hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 11/21/97		3. REPORT TYPE AND DATES COVERED Final Technical Report
4. TITLE AND SUBTITLE Correlations between <i>Halobates</i> distributions and physical processes at the sea surface				5. FUNDING NUMBERS N00014-95-1-0142
6. AUTHOR(S) Lanna Cheng				
7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(ES) Scripps Institution of Oceanography Marine Biology Research Division La Jolla, CA 92093-0202				8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Naval Research Dr. Ronald C. Tipper, ONR 322BC 800 North Quincy Street Arlington, VA 22217-5660				10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION/AVAILABILITY STATEMENT				12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 words) Five sea-skater species, each with a well-defined geographical range, are specifically adapted to live on the surface film. 1) Analyses of an 18-month time series showed that the range of <i>Halobates micans</i> and <i>H. sericeus</i> in the Pacific Ocean are generally separate. <i>H. micans</i> is restricted to a zone between 11 deg. N and 10 deg. S., with amphitropical populations of <i>H. sericeus</i> north and south of this region. The separate ranges of the two species are associated with permanent large-scale surface circulation patterns. 2) Theoretical calculations showed that oceanic diffusion alone could carry <i>Halobates</i> from an initial point of origin to 2500 m in 60 days. Mutual encounter rates due to oceanic turbulence could be as high as 11/day even at low population densities (110/km ²), while the encounter rate due to random movements is less than 0.6/day. An individual could find mates even when it had been carried long distances away. 3) Preliminary results from mtDNA sequences of regions of cytochrome oxidase subunit I (COI) revealed that although North Atlantic and Arabian Sea <i>H. micans</i> appear to be closely related, there was high genetic divergence between N. Pacific and Arabian Sea populations.				
14. SUBJECT TERMS Surface film, oceanic diffusion, sea-skaters, <i>Halobates</i> , disjunct distribution, genetic exchange, mtDNA sequences				15. NUMBER OF PAGES 6
				16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unrestricted		18. SECURITY CLASSIFICATION OF THIS PAGE Unrestricted		19. SECURITY CLASSIFICATION OF ABSTRACT Unrestricted
				20. LIMITATION OF ABSTRACT None

Final Technical Report (ONR-N00014-95-1-0142)

Principal Investigator: Lanna Cheng
University of California, San Diego
Scripps Institution of Oceanography
Marine Biology Research Division
La Jolla, California 92093-0202
E-mail : lcheng@ucsd.edu
TEL: (619) 534 4836
FAX: (619) 534 7313

CORRELATIONS BETWEEN HALOBATES DISTRIBUTIONS AND PHYSICAL PROCESSES AT THE SEA SURFACE**LONG-TERM GOALS**

Five species of Halobates (Hemiptera: Gerridae) are specially adapted to a pelagic life. They all occur in the Pacific Ocean, each with a well-defined geographical range. Since these insects live their entire lives on the sea surface, they are uniquely suited for studying sea-surface processes. The proposed study will enable us to test the validity of conventional theories of oceanic diffusion as it affects the distribution of strictly sea-surface objects, and will perhaps provide clues to solving problems of surface-film diffusion. If we can elucidate factors controlling the distribution patterns of Halobates species we may be able to use these insects as marker organisms for climatological studies at the sea surface, helping us to better understand air-sea exchange processes at the surface film which are important in modelling the global circulations of atmosphere and ocean.

SCIENTIFIC OBJECTIVES

Oceanic diffusion is not only of theoretical interest but also of practical importance, especially in relation to the distributions of surface pollutants and other contaminants. It is a complex process, and many theories have been put forward to explain it. One of these, the diffusion diagram developed by Dr. Akira Okubo, can be used to predict the rate of horizontal spread of a substance from an instantaneous point source. It is applicable to submerged materials and passive contaminants, but we do not know if it also applies to the diffusion of strictly surface-floating objects. The present project aims to investigate what controls the distribution ranges of Halobates, and to test the validity of existing oceanic diffusion laws by using this flightless insect as a model organism.

19971201 043

APPROACH

We used two approaches:-

- 1) Analyses of distribution patterns of Halobates spp., and comparisons with various conventional physical parameters.
- 2) Using contemporary genetic methodologies to compare the mitochondrial-DNA sequences of Halobates species.

TASKS COMPLETED

A) Samples from an 18-month time series collected between Hawaii and Tahiti were analysed. Two species of Halobates were caught: H. sericeus, with an amphi-tropical distribution, and H. micans, occupying the equatorial zone separating the northern and southern populations of the former. How this disjunct distribution pattern may be maintained by zonal equatorial current systems was investigated.

B) Using oceanic diffusion diagrams constructed by Okubo and the mathematical model developed by Kierstead and Slobodkin, and Skellam, effects of oceanic diffusion on 1) Patch expansion, 2) Mutual encounter rates, and 3) Growth rates of Halobates were investigated.

C) About 100 samples of Halobates were collected for DNA studies. All 5 pelagic species (H. micans, H. sericeus, H. germanus, H. sobrinus and H. splendens) were represented as well as the following coastal species: H. hawaiiensis, H. flaviventris, H. robustus, H. fijiensis, H. salotae, H. mariannarum, and H. nereis. DNA was extracted from some of the specimens on site, or from samples preserved either in liquid nitrogen or 80% ethanol after they had been received at the laboratory.

RESULTS

A) The time series analysed shows that, even on a limited temporal and spatial scale, the ranges of H. micans and H. sericeus in the Pacific Ocean are generally separate. H. micans is restricted to a zone between 11°N and 10°S, with amphotropical populations of H. sericeus north and south of this region. The separate ranges of the two species are associated with permanent large-scale surface circulation patterns. However, although the separation of northern and southern populations of H. sericeus appears to be permanent, there is evidence of mixing between the two species. Data from the present series do not allow us to speculate on whether inter-mingling of individuals from the two populations ever occurs. We are sequencing mitochondrial-DNA fragments of preserved H. sericeus specimens in an attempt to find out whether the two disjunct populations are genetically distinct.

B) In theory the estimated diameter of a patch of Halobates could be expanded by oceanic diffusion alone from an initial point of origin to 2500 km in 60 days (i.e. the average time required for an egg to develop into an adult). This distance is about one-sixth of the maximum distributional range of H. micans in the Pacific Ocean. It is possible that within its range each species forms only one mega-population in which local aggregates may be found.

Mutual encounter rates due to oceanic turbulence could be as high as 11 /day even at low population densities ($100/\text{km}^2$), while the encounter rate due to random movements is less than 0.6/ day. This suggests that a Halobates could find a mate even when an individual had been carried a long distance away from its initial patch. Thus, extensive gene mixing may occur over the whole range of a species' distribution.

Estimated growth rates for pelagic Halobates are rather low (0.0026-0.0079/day) compared with those of other insects. However, they are offset by a long life span (over 60 days) and an extended oviposition period (perhaps over 2 months).

c) We were able to amplify and sequence certain fragments of the cytochrome oxidase subunit I (COI) region of the mtDNA of Halobates. This molecule has been found to be an excellent genetic marker for phylogenetic and systematics studies in several other insects. Using primers developed specifically for the Gerridae by Dr. Felix Sperling at UC Berkeley we were able to obtain complete sequences for two regions containing 440 and 436 base pairs respectively, with some overlap between the two. Preliminary analyses indicated a high degree of genetic divergence between North Pacific and Arabian Sea H. micans, but close similarity between North Atlantic and Arabian Sea populations. The coastal H. hawaiiensis was also found to be closely related to H. micans. This work is continuing.

WORK STILL IN PROGRESS:

1. Distributions: With the collaboration of Drs. Hidehiko Okabe and Terumi Ikawa, a computer databank containing some 5,000 sample data has been established at the National Institute for Material Sciences, Tsukuba, Japan. This database contains information for all 5 pelagic Halobates species. We plan to correlate the distribution patterns of each species with surface temperatures, winds and currents obtained from SVP drifters.

2. Modelling: In collaboration with Dr. Mark Luther's group at the Department of Marine Science, University of South Florida, St. Petersburg and Dr. Martien Baars, Netherlands Institute of Sea Research, we are trying to find out how the distributions of Indian Ocean Halobates agree with those of passive tracers like FCC's simulated by Luther's model. Similar studies are being carried out by Dr. Don Olson, RSMAS, University of Miami, using

models involving surface currents and winds derived from data obtained by Lagrangian drifters.

3. Molecular studies: Work on mtDNA sequencing in collaboration with Drs. Felix Sperling and Andrew Shedlock, University of California, Berkeley, is continuing. This project did not proceed as smoothly as we had hoped since we have encountered several problems which had not been anticipated. For most other insect species studied in the Sperling lab PCR results were predictable when similar primers were used. In the case of Halobates we found unpredictable PCR results even though samples had been collected, extracted and processed in the same way. We are trying to solve this problem.

PAPERS PUBLISHED, IN PRESS OR SUBMITTED:

Lanna Cheng and Patricia Holdway. Populations of Halobates (Hemiptera: Gerridae) across two oceans. *Raffles Bulletin of Zoology*, 43(2): 313-327 (1995).

Lanna Cheng. Disjunct distributions of Halobates (Hemiptera: Gerridae) in the Pacific Ocean. *Pacific Science*, 51(2): 134-142 (1997).

Terumi Ikawa, Akira Okubo, Hidehiko Okabe and Lanna Cheng. Oceanic diffusion and the distribution of Halobates. *Proceedings ICoPB-II*, pp. 193-195. UNESCO Publications (1997).

Terumi Ikawa, Akira Okubo, Hidehiko Okabe and Lanna Cheng. Oceanic diffusion and the pelagic insects Halobates spp. (Gerridae: Hemiptera). *Marine Biology* (in press).

Lanna Cheng and Vassilios Roussis. Surface-active sex-attracting substances produced by males of the marine insect Trochopus plumbeus (Heteroptera: Veliidae). Submitted to *Journal of Chemical Ecology* May 1997.

PAPERS PRESENTED AT NATIONAL OR INTERNATIONAL MEETINGS

Lanna Cheng: Disjunct distributions of Halobates sericeus in the Pacific Ocean. (Oral presentation, Second International Conference on Pelagic Biogeography, Leeuwenhorst, The Netherlands, July 1995).

Terumi Ikawa, Akira Okubo, Hidehiko Okabe and Lanna Cheng: Oceanic diffusion and the distribution of Halobates. (Poster presentation : Second International Conference on Pelagic Biogeography, Leeuwenhorst, The Netherlands, July 1995).

Lanna Cheng: Disjunct Distributions of Halobates sericeus in the Pacific Ocean. (Oral presentation, Ocean Sciences Meeting, San Diego, CA. February 1996).

Terumi Ikawa, Akira Okubo, Hidehiko Okabe and Lanna Cheng: Oceanic diffusion and the distribution of Halobates. (Poster presentation, Ocean Sciences Meeting, San Diego, CA. February 1996).

Lanna Cheng: Marine insects. (Oral presentation, Symposium on the Ecology of Marine Insects, XX International Congress of Entomology, Firenze, Italy, August 1996).

Lanna Cheng: Ecology of Halobates. (Oral presentation, Symposium on the Ecology of Marine Insects, XX International Congress of Entomology, Firenze, Italy, August 1996).

Vassilios Roussis and Lanna Cheng: The chemical attractant of male Trochopus (Hemiptera: Veliidae): a preliminary report. (Oral presentation, Symposium on the Ecology of Marine Insects, XX International Congress of Entomology, Firenze, Italy, August 1996).

Terumi Ikawa, Hidehiko Okabe and Lanna Cheng: How oceanic surface environments affect the distribution of pelagic Halobates (Hemiptera: Gerridae). (Oral presentation, Symposium on the Ecology of Marine Insects, XX International Congress of Entomology, Firenze, Italy, August 1996).

Andrew Shedlock, Felix A.H. Sperling and Lanna Cheng: Mitochondrial DNA and Halobates (Hemiptera: Gerridae): a technique for tracing tiny trans-ocean travelers. (Oral presentation, Symposium on the Ecology of Marine Insects, XX International Congress of Entomology, Firenze, Italy, August 1996).